THE MINIATURISED MÖSSBAUER SPECTROMETERS MIMOS II ON MER: FOUR YEARS OF OPERATION – A SUMMARY. I. Fleischer[1], G. Klingelhöfer[1], R.V. Morris[4], D. Rodionov[1,2], M. Blumers[1], B. Bernhardt[3], C. Schröder[1,4], D.W. Ming[4], A.S. Yen[7], B.A. Cohen[8], T.J. McCoy[9], D.W. Mittlefehldt[4], M.E. Schmidt[9], J. Girones Lopez[1], G. Studlek[1], J. Brückner[5], R. Gellert[10], and C. d'Uston[6]. [1]Johannes Gutenberg Universität Mainz, Institut für Anorganische und Analytische Chemie, Staudinger Weg 9, D-55099 Mainz, Germany (klingel@mail.uni-mainz.de). [2]Space Research Institute IKI, Moscow, Russia. [3]Von Hoerner&Sulger GmbH, Schwetzingen, Germany. [4]NASA Johnson Space Center, Houston, Texas, USA, [5]MPI Chemie, 55128 Mainz, Germany, [6]CESR Toulouse, France, [7]Jet Propulsion Laboratory, Pasadena, CA, USA, [8]Marshall Space Flight Center, Huntsville, AL, USA, [9]Smithsonian Institution, Washington, DC, USA, [10]University of Guelph, Guelph, Canada.

Introduction: The two Miniaturised Mössbauer Spectrometers (MIMOS II, Figure 1) on board the two Mars Exploration Rovers "Spirit" and "Opportunity" have now been collecting important scientific data for more than four years. The spectrometers provide information about Fe-bearing mineral phases and determine Fe oxidation states. [1-6]. The total amount of targets analized exceeds 600, the total integration time exceeds 260 days for both rovers. Since landing, more than five half-lives of the Co^{57} MB sources have past (intensity at the time of landing ~150 mCi). Current integration times are about 50 hours in order to achieve reasonable statistics as opposed to 8 hours at the beginning of the mission.

In total, 13 different mineral phases were detected: Olivine, pyroxene, hematite, magnetite and nanophase ferric oxide were detected at both landing sites. At Gusev, ilmenite, goethite, a ferric sulfate phase and a yet unassigned phase (in the rock "Fuzzy Smith") were detected. At Meridiani, jarosite, metallic iron in meteoritic samples (kamacite), troilite, and an unassigned ferric phase were detected. Jarosite and goethite are of special interest, as these minerals are indicators for water activity [3-5]. In this abstract, an overview of Mössbauer results will be given, with a focus on data obtained since the last martian winter.

Figure 1: The current version of the MIMOS II sensorhead

The MER mission has proven that Mössbauer spectroscopy is a valuable tool for the in situ exploration of extraterrestrial bodies and for the study of Fe-bearing samples. The experience gained through the MER mission makes MIMOS II a obvious choice for future missions to Mars and other targets. Currently, MIMOS II is on the scientific payload of two approved future missions: Phobos Grunt (Russian Space Agency; 2009) and ExoMars (European Space Agency; 2013).

MER-A Spirit: Spirit has traversed the plains from her landing site towards the Columbia Hills. Since sol 744, the rover has been investigating the area around Home Plate, a layered plateau in the Inner Basin of the Columbia Hills. Home Plate is probably of explosive volcanic origin [8]. Mössbauer spectra were obtained on the Northwest side of Home Plate (sols 748-762), on the East side (sols 1170-1220), on the South side (sols 1328-1330), and on the West side (sols 1411-1422). Spectra obtained in one location show very little variation, but spectra from different locations show substantial variation. The minerals pyroxene and magnetite were identified in all spectra obtained on Home Plate rocks. Spectra obtained on the East side show little or no olivine and little Nanophase ferric oxide (npOx), while spectra obtained on the West side show increased amounts of both mineral phases.

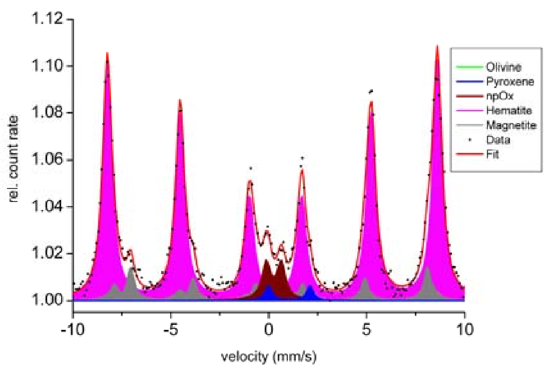

Figure 2: Mössbauer spectrum obtained on Troll-Montalva with a hematite (magenta) content of 78%.

For a more detailed description of MB Home Plate spectra, see [9].

In the immediate vicinity of Home Plate, materials with a very high silica content were found, suggesting hydrothermal alteration [10, 11]. Southeast of Home Plate, pervasively altered, hematite-rich materials were investigated in the targets Enderbyland_Halley, Grahamland_KingGeorgeIsland, and in the troll outcrop [12]. The highest hematite content (78%) was discovered in the target Montalva on the Troll outcrop (Figure 2).

MER-B Opportunity: Opportunity has travelled more than 11 km from her landing site in 20 m diameter Eagle crater to 800 m diameter Victoria crater, analysing outcrop exposures along her traverse. In November 2007, Opportunity began ingress into Victoria crater and is currently (January 2008) analysing the three stratigraphic units Steno, Smith and Lyell [e.g. 13]. There is only little variation in the Fe mineralogy along Opportunity's traverse. Mössbauer spectra obtained on outcrop rocks show the mineral jarosite, an indication for past water activity at Opportunity's landing site. Figure 3 shows a typical Mössbauer spectrum obtained on Meridiani outcrop. Figure 4 shows a spectrum obtained on the Smith-layer in Victoria crater in direct comparison with a spectrum obtained on the McKittrick outcrop in Eagle crater at the beginning of the mission.

Two float rocks (Barberton and HeatShieldRock) investigated by Opportunity have been identified as a stony meteorite and an iron meteorite, respectively. Their Mössbauer spectra show the Fe-Ni alloy kamacite. A third candidate meteorite is the cobble Santa-Catarina, which is chemically similar to Barberton. Instead of kamacite, troilite was detected in this rock [14].

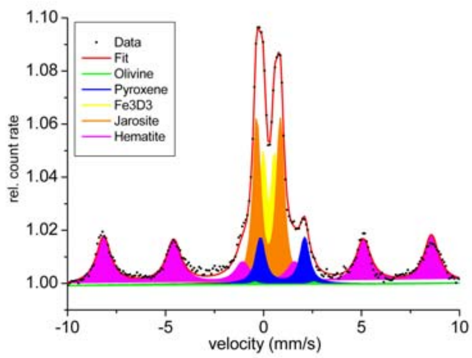

Figure 3: typical outcrop spectrum (obtained on McKittrick in Eagle crater), showing the Fe hydroxide mineral jarosite (orange).

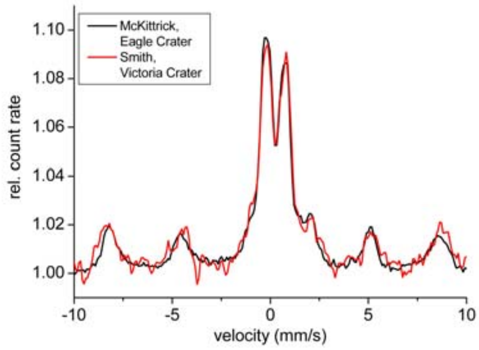

Figure 4: comparison of a MB spectrum obtained on the McKittrick outcrop in Eagle crater at the beginning of the MER mission (black), and a spectrum obtained on the Smith layer in Victoria crater (red).

Summary: The MER Mössbauer instruments have proven that Mössbauer spectroscopy is a powerful tool for planetary exploration. The primary MER objectives have been successfully completed. Both MB spectrometers continue to accumulate valuable scientific data after four years of operation . The identification of aqueous minerals such as goethite in Gusev crater and jarosite at Meridiani Planum by the MER MB spectrometers is strong evidence for past water activity at the two landing sites.

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References: [1] Klingelhöfer et al., J. Geophys. Res. 108(E12) (2003) doi:10.1029/2003JE002138. [2] Klingelhöfer et al., Science 306 (2004) 1740-1745. [3] Morris et al., Science 305 (2004) 833-836. [4] Klingelhöfer et al., Hyp. Int. 166 (2005) 549-554. [5] Morris et al., J. Geophys. Res. 111 (2006) doi:10.1029/2005JE002584. [6] Morris et al., J. Geophys. Res. 111 (2006) doi:10.1029/2006JE002791. [7] Klingelhöfer (1999); in: Mössbauer Spectroscopy in Materials Science, eds. M.Miglierini and D.Petridis, Kluwer Academic Publishers 1999. [8] Squyres S.W. et al. (2007) *Science, 316*, 738-742. [9] Schröder et al. (I), this conference. [10] Morris et al., this conference. [11] Ming et al., this conference. [12] Schröder et al. (II), this conference. [13] Mittlefehldt et al., this conference. [14] Schröder, C. et al. (2007), *JGR*, in press.